BEAM TRAMMELS and TAPE MEASURES are used for striking lines at 90° to each other, and for measuring distances accurately. It is common practice for the craftsman to use a pair of trammel heads or 'trams' and any convenient beam such as a length of wooden batten. Figure 5.4 shows the arrangement of the trammel and the simple means of fine adjustment for accurate marking out.

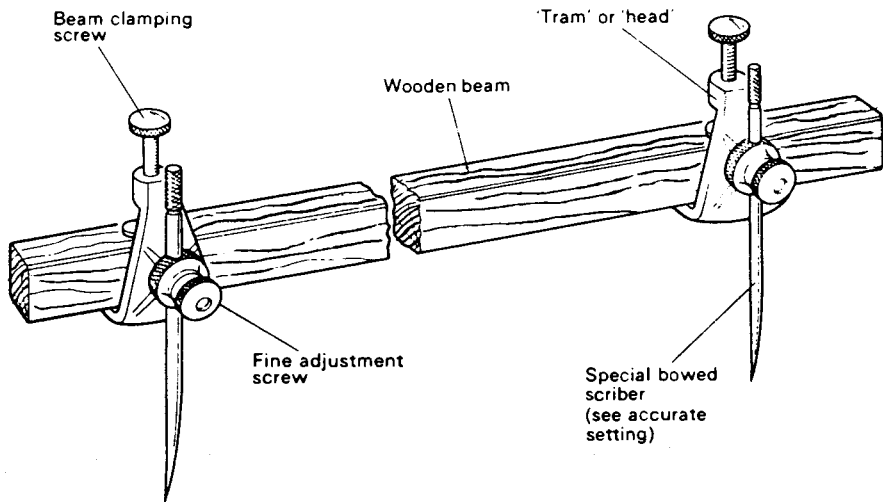
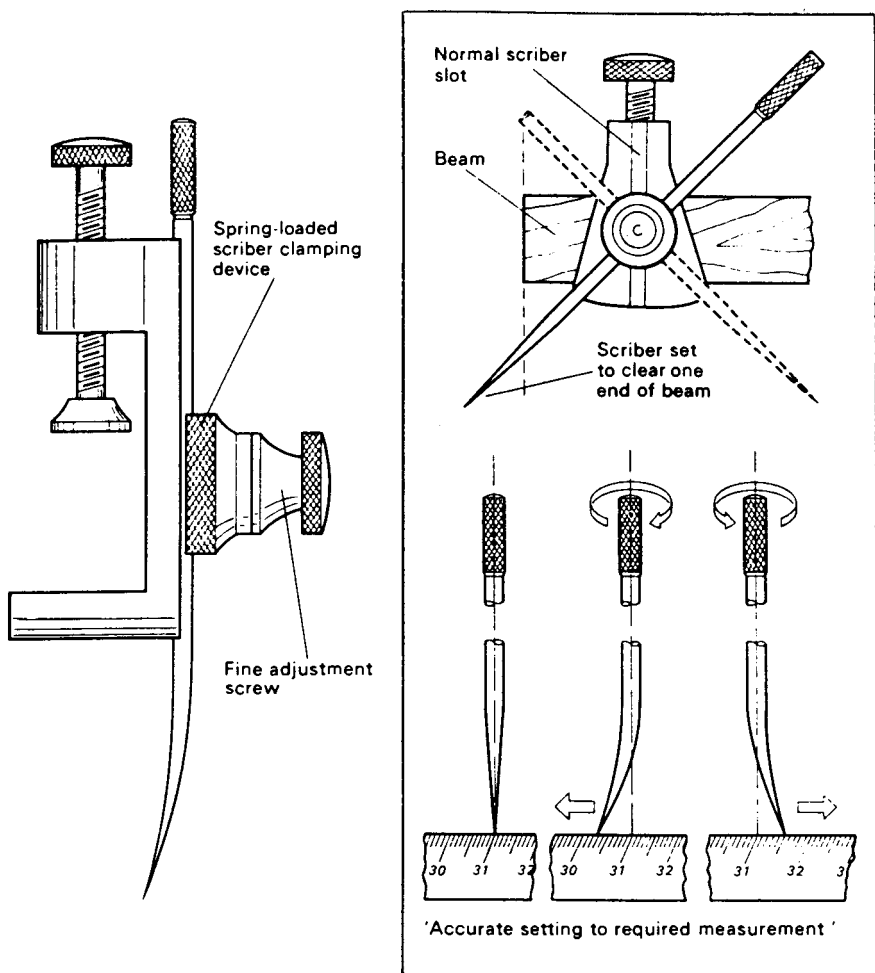



Fig. 5.4 Beam trammels

Lines making angles of 90°, i.e. lines square with each other, may be set out with the aid of beam trammels or a steel tape, as shown in Fig. 5.5(*a*).

A KNOWLEDGE OF GEOMETRIC CONSTRUCTIONS AND ARITHMETIC IS ESSENTIAL FOR MARKING OUT.

NOTE: Where possible existing straight edges and square corners on the plate to be marked should be used.

The normal accuracy obtainable when marking out with DIVIDERS, ODD-LEGS and TRAMMELS is within 0·15mm of the TRUE DIMENSION.

Beam trammels

C

90°

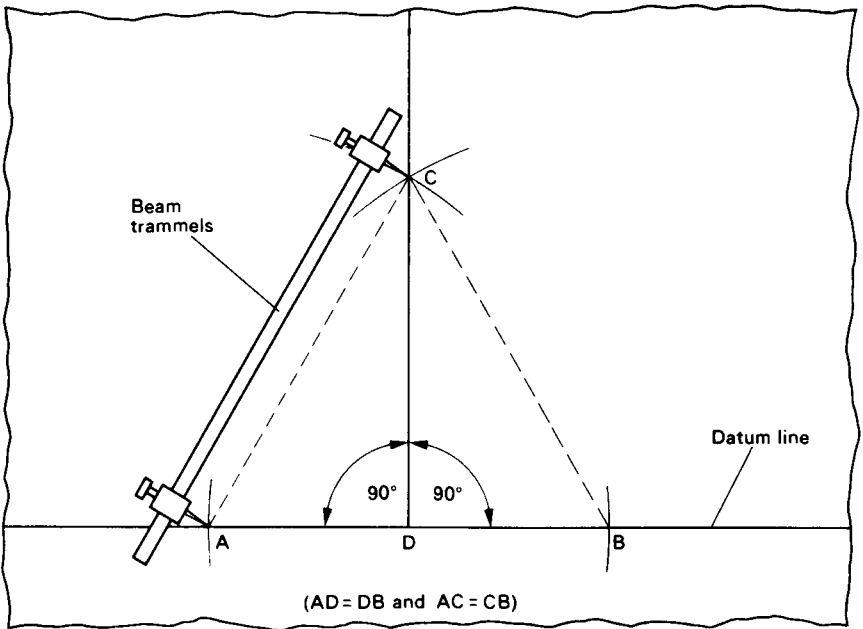
90°

Datum line

A

D

B

(AD = DB and AC = CB)

(a) **Use of trammels to construct a right angle**

C

3

5

Datum line

90

4

A

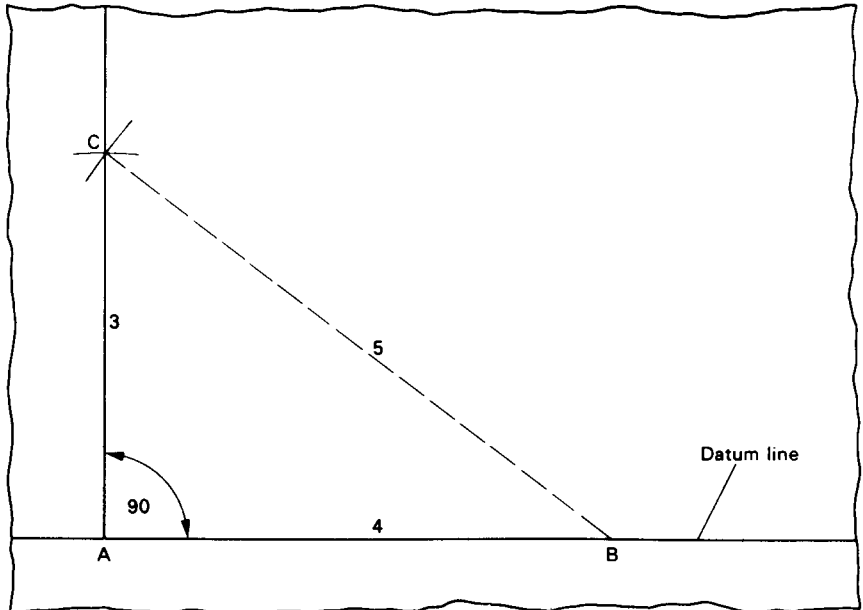
B

(b) **Use of trammels and steel tape to construct a right angle**

Fig. 5.5 Applications of beam trammels and steel tape (marking out)

Figure 5.5(*b*) shows how the properties of a right-angled triangle can be used to set out perpendicular lines (*Basic Engineering,* section 3.16).

If the ratio of the sides of a triangle is 3:4:5 then it is a RIGHT ANGLE TRIANGLE.

Scribe a datum line on the plate and mark off a length A B representing 4 units of measurement with a steel tape or beam trammels. Centre-punch mark points A and B. With centre A and the trammels set at a distance equal to 3 units, scribe an arc. With centre B and the trammels set at a distance equal to 5 units scribe another arc. The two arcs intersect at a point C which is marked with a centre punch. With a chalkline mark a line passing through the witness marks A and C.

5.5 Basic methods used for marking-off large-size plates

For economic reasons advantage should always be taken of as many good and straight edges as possible before commencing marking off large-size plates for cutting. *Unnecessary shearing or flame-cutting can be avoided if the edges of the steel plates are examined before marking-off.*

Any one or a combination of THREE BASIC METHODS may be used for obtaining parallel and squared lines to enable a plate to be cut to the required dimensions:

Method 1 Use of square and steel tape

A FLAT SQUARE is used for marking out on large flat surfaces. The flat square differs from an Engineer's try-square in that it is laid on the flat surface of the sheet metal or plate to be marked out. It is larger than the try-square and is made in one piece, consisting of a long arm termed the 'body' and a short arm termed the 'tongue'. The body and tongue are of uniform thickness and form a 90° angle, as illustrated in Fig. 5.6. In many fabrication workshops use is made of a simple made-up square of either wood or light guage steel.

A suitable steel tape is used in conjunction with the flat square.

Select one straight edge on the plate, and with the aid of a flat square and a stick of French chalk, mark a line at 90° to this datum. Extend this line using a chalkline. From these two datums the required dimensions are marked off with French chalk. A steel tape is

(a) **The fabricated flat square**

(b) **The steel flat square** (one piece)

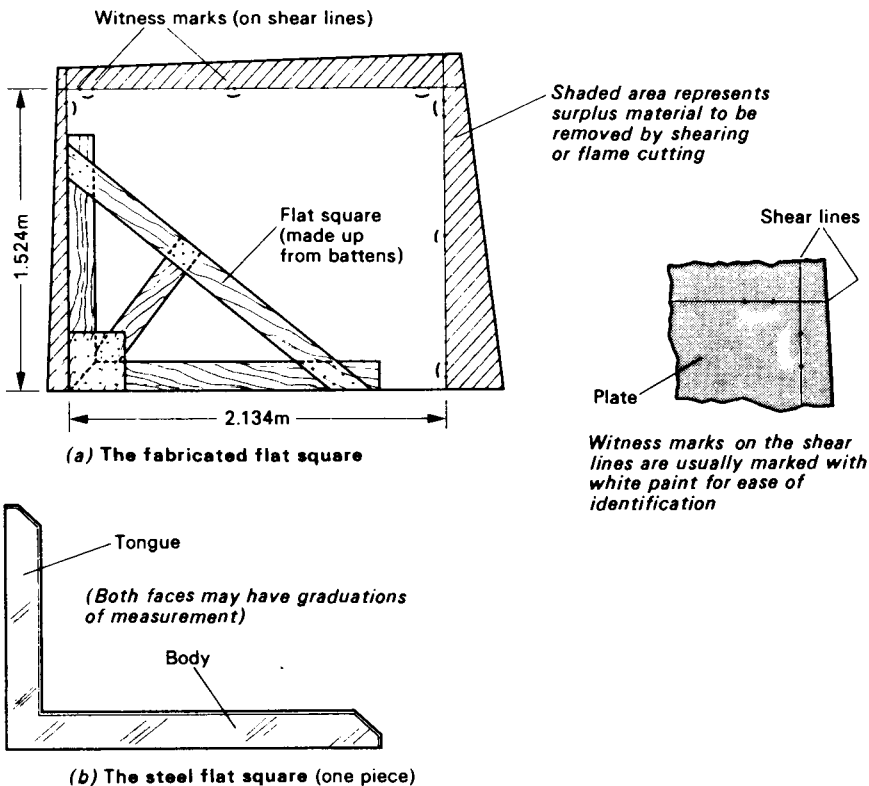



Fig. 5.6 The flat square

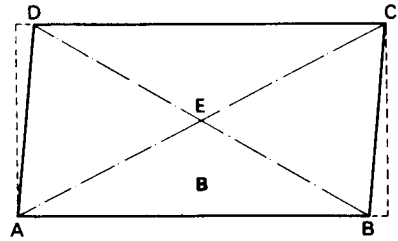
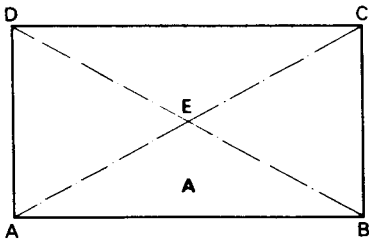
used for measuring all dimensions. The shear lines are completed with the aid of a chalkline, and witness marks are made on them with a centre punch.

Before commencing to mark out a large plate:

1. Always check for squareness
2. Where possible, select one straight edge and use as a base datum.

Figure 5.6 showed how a square and steel tape are used for marking-off a steel plate for cutting. Figure 5.7 shows how squareness may be checked.

Method 2 Use of steel tape

A plate of any size may be marked-off with square corners by measuring with a steel tape, units of length in the proportion of 3, 4 and 5 to produce the datum lines at right angles to each other.

Checking long rectangular outlines

TRUE SQUARENESS of marking may be easily *checked by measuring diagonal corner distances*

A — In an OBLONG or RECTANGULAR figure, the diagonals bisect each other such that A-E = C-E = B-E = D-E. The diagonals A-C and B-D are equal, therefore the angles in a rectangle, or square are each 90°

B — In a PARALLELOGRAM the diagonals bisect each other such that: A-E = E-C and B-E = E-D The diagonals A-C and B-D are NOT EQUAL therefore none of the angles are 90°

This principle is used to check large rectangular outlines for squareness when marking out

Fig. 5.7 Checking large rectangular outlines

Figure 5.8 illustrates the use of a steel tape for marking-off a plate to measure 1·65m by 1·23m.

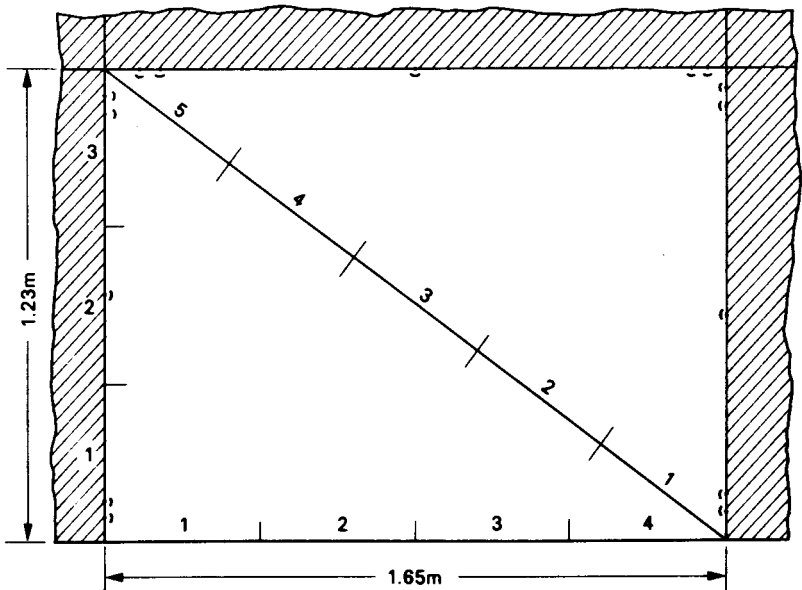



Fig. 5.8 Use of the steel tape for marking off

Select one straight edge on the plate for straightness and use as a base line, otherwise mark a datum line with the aid of a chalkline.

In this example the plate is required to be marked out 1·23m by 1·65m, using a steel tape only.

The method employed has been explained in Fig. 5.6.

In this case a most suitable measurement to be used for the 3:4:5 ratio of the sides of a 90° triangle will be 410 mm, giving the following dimensions to be used for the steel tape:

1 230 mm (3 x 410) : 1 640 mm (4 x 410) : 2 050 mm (5 x 410)

Once a line has been constructed at 90° to the base datum, the dimensions of the sides are measured with the steel tape, the outlines made with a chalkline and witness marked.

The outline is checked for true squareness as explained in Fig. 5.7.

Arcs may be swung with a steel tape by holding the French chalk in the hook at the zero end of the tape.

Method 3 Use of steel tape and trammels

Figure 5.9 illustrates the method of marking-off a steel plate which is required to be 1·58 m x 1·58 m with square corners, using a steel tape and trammels.

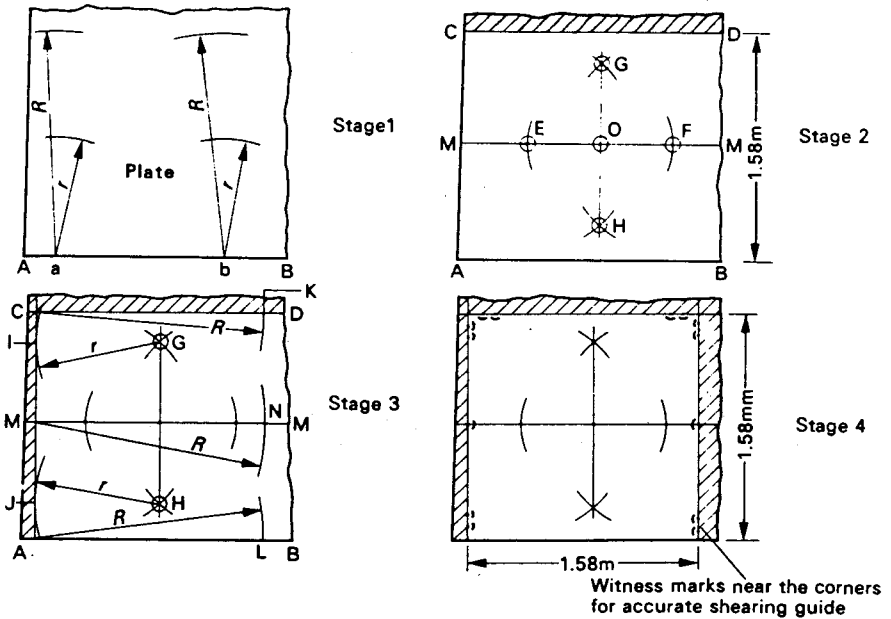



Fig. 5.9 Marking-off with a steel tape and trammels

Stage 1 A suitable straight edge is selected and used as a base line, as shown at A—B.

The trammels are set to the full width of the plate (R = 1·58 m) and with any two points 'a' and 'b' (on the base line A—B) as centres, arcs are struck. With the same centres and the trammels set to approximately half this dimension (radius r) two other arcs are shown struck as in Fig. 5.9.

THE STEEL TAPE IS USED FOR ALL MEASUREMENTS

Stage 2 Parallel lines, C—D and M—M are marked with the chalk-line held tangential to each pair of equal arcs, in turn.

A light centre punch mark is made at O which is approximately half the width M—M.

From the point O on M—M construct a perpendicular G—H, and mark with the chalkline. Lightly centre-punch mark the points G and H.

The points, G, H and O are used to check whether the edges of the plate are straight and parallel to this line of points, to enable use to be made of them.

Stage 3 If both edges prove unsuitable for use, the trammels are set to radius r, and with centres G and H, arcs are struck to provide a suitable shearing margin at points I and J.

The end shear line is made with the chalk line held at a tangent to these arcs.

The plate edge measurements for the length of the plate are made from this line (through I and J). The trammels are set to R = 1·58 m, and a chalkline is made at a tangent to the arcs at points K, N and L, as shown in Fig. 5.9.

Stage 4 The shear lines are witness marked with a centre punch, and white paint marks are made near them.

The finished outline is checked for SQUARENESS by measuring the diagonal lengths.

5.6 Method of marking out bolt holes for flanges

Many fabrications such as boilers, chemical plant and pressure vessels incorporate the use of flanged inlets and outlets. Manholes and inspection covers are also bolted to flanges. Pipes of various diameters are connected by means of flanges.

The flanges are welded to the fabrications and on the ends of pipes, and the connections are made by bolting. Figure 5.10 illustrates the method of laying out the bolt holes on flanges. In practice the standard size of the required flange, the PITCH CIRCLE DIAMETER and the number and size of the bolts is specified in B.S. 1560.

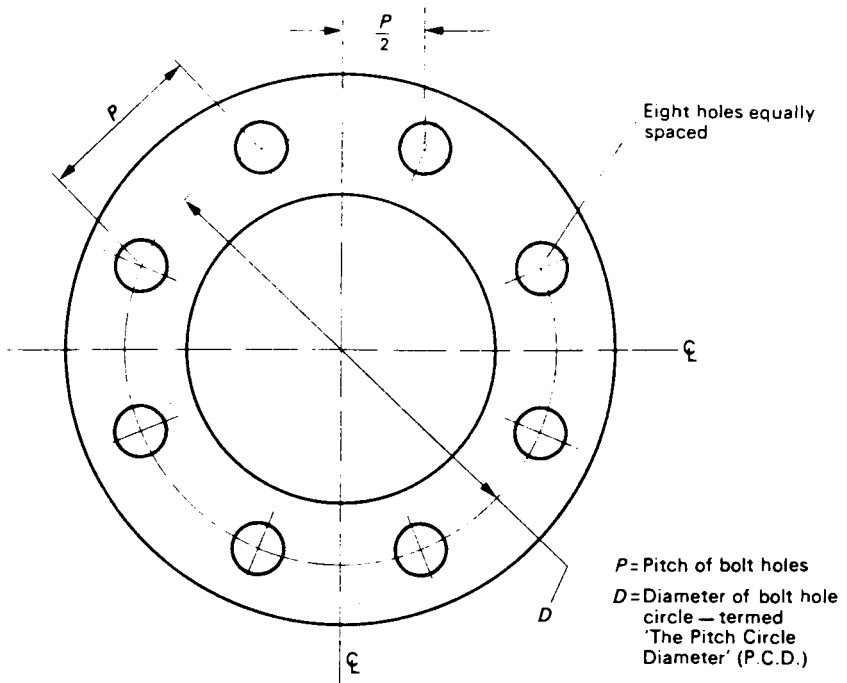



Fig. 5.10 Marking-out bolt holes for flanges

The centre of the flange is plugged with a suitable piece of wood or piece of flat bar, which is 'tack-welded' in position, to enable the centre of the flange to be located. On flanges up to about 460 mm in diameter horizontal and vertical centre lines (℄) may be marked with the aid of a height gauge in conjunction with an angle plate on a marking out table, and a pair of trammels. On very large diameter flanges, use is made of a large centre-square to locate the centre for the bolt hole circle.

For any specific size of flange for a particular class of work, details such as the BOLT CIRCLE DIAMETER, *NUMBER OF BOLT HOLES and DIAMETER OF BOLTS are obtained from the appropriate standard table (see Tables 5.1 and 5.2).*

Table 5.1 Data for marking out pipe flanges

FLANGE SIZE DESIGNATION (Nominal bore of pipe) (mm)	APPROXIMATE O.D. OF STEEL PIPE (mm)	DIAMETER OF FLANGE (mm)	BOLT CIRCLE DIAMETER (mm)	NUMBER OF BOLTS	DIAMETER OF BOLT (mm)
152	165	279	235	4	16
254	273	406	356	8	19
305	324	457	406	8	22
432	457	610	523	12	25
584	610	787	724	12	25
686	711	870	857	16	25
889	914	1 073	1 016	24	25
1 067	1 092	1 251	1 194	28	25
1 524	1 549	1 784	1 702	32	25
1 829	1 861	2 108	2 019	36	35

The above data is a selection of recommended flange sizes for steel pipes from BS 1560 Class 150 to withstand working pressures up to 1 034 kN/m^2 (10·5 kgf/cm^2)
Bolt-holes in flanges are marked out in accordance with Standard Tables, and the holes drilled to suit the correct diameter of bolt.

Table 5.2 Constants for bolt hole location (flanges)

NUMBER OF BOLT HOLES	CONSTANT (to be multiplied by Bolt Circle Diameter or P.C.D.)
4	0·407 1
8	0·382 7
12	0·258 8
16	0·195 1
20	0·156 4
24	0·130 5
28	0·112 0
32	0·098 0
36	0·087 2

Use of tables: Example
To mark out a 305 mm Class 150 Standard Flange.
From Table 5.1, the P.C.D. = 406 mm and the number of bolts = 8.
(The diameter of the flange = 457 mm)
The pitch (chord length of bolt holes centres) = the 'P.C.D.' multiplied by the 'constant' from Table 5.2.
The 'constant' for 8 holes = 0·382 7
Therefore, 'pitch' = 406 x 0·382 7
P = 155·76 mm

For any number of holes not shown in the table, multiply the SINE of HALF THE SUBTENDED ANGLE between a pair of holes by the 'P.C.D.'

$$\text{The subtended angle} = \frac{360}{\text{Number of holes}}$$

Example:
Number of holes = 15

$$\text{Subtended Angle} = \frac{360}{15} = 24°$$

The constant = Sine 12° = 0·2079 (for 15 holes)

Having located the centre and marked the horizontal and vertical centre lines, the appropriate bolt circle is marked by means of trammels.

The pitch is constant and is usually obtained from tables of 'bolt hole locations' which *provide a constant which has to be multiplied by the diameter of the bolt hole circle to obtain the required pitch.*

To obtain the position of the first bolt hole, divide the pitch by 2, set the dividers to this dimension and mark off from the intersection of the vertical centre line and the bolt circle, and centre punch.

The remainder of the bolt hole centres may now be located with the dividers set at the correct pitch (CHORD LENGTH) and centre-punched in readiness for drilling to required size.